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Science culture in Brazilian society

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Introduction

In recent decades, Brazil has invested significant amounts of resources and energy into expanding its science, technology and innovation sector. Expenditure on science, technology and innovation reached 1.21 per cent of GDP in 2012, the largest percentage in absolute and relative terms in the Latin American region. This is a comparable figure to 1.74 per cent in Canada or 1.84 per cent in China but remains far below that of Germany, Korea and Japan, all of which spent 3 per cent or above. Currently, Brazil has about 100,000 researchers and 71,000 students enrolled in 1,600 doctoral programmes, producing 12,000 graduates every year, 45 per cent of them in STEM fields (natural sciences and engineering) (Viotti and Pinho 2010 (Viotti & Pinho, 2010 p.98). In 2009, Brazilian authors published 32,100 papers in indexed publications internationally, comprising 54 per cent of total papers from Latin America and 2.7 per cent of those worldwide[1]

Graduate and research programmes, however, are just part of a much larger and very differentiated higher education sector. Only about 13 per cent of the adult population holds a higher education degree, and this number is not undergoing a very significant increase. The net enrolment rate (percentage of persons ages 18–24 in higher education) is approximately 15 per cent. Brazil does not have undergraduate colleges like the US or UK. All students enter a career programme that can last from four to six years, working for a teaching license or a bachelor's degree, and some then move up to master's, doctoral or specialization course programmes.

[1]Data on expenditures and publications comes from the Brazilian Ministry of Science,

The higher education census of 2012, carried out by the Ministry of Education, identified 7 million first-degree students (including 1.1 million students in distance education courses and 1 million students who graduated in the same year) (INEP, 2013). The survey shows that 63 per cent of students are enrolled in the social sciences, humanities and teaching, and 18.7 per cent in engineering, computer sciences and mathematics. Sixty per cent of the students are women, heavily concentrated in education, health and welfare, while men predominate in mathematics, computer sciences and engineering. In postgraduate education, the distribution by field shows a stronger emphasis on the natural sciences, particularly in health.

Enrolment in Higher Education by gender and field, 2012

	Total		% of women
Education	1,371,600	19.4%	72.5%
Humanities and Arts	161,745	2.3%	55.9%
Social Sciences, business and Law	2,916,189	41.3%	56.6%
Sciences, Mathematics, Computation	433,836	6.1%	30.9%
Engineering, production and construction	891,712	12.6%	30.3%
Agricuture and Veterinarian sciences	165,075	2.3%	44.2%
Health and well-being	961,915	13.6%	76.6%
Services	153,427	2.2%	60.6%
Total	7,058,084	100.0%	60.6%

Source: Ministry of Education, Census of Higher Education, 2012, Microdata tabulated by the author
http://portal.inep.gov.br/basica-levantamentos-acessar

Table 2 Number of post-graduate degrees granted, 2012

	Doctoral	Master's
Agrarian Sciences	13.3%	11.7%
Bilogical Sciences	10.2%	7.7%
Health Sciences	18.7%	15.6%
Exact Sciences and Sciences of the ear	9.7%	8.8%
Humanities	16.5%	17.1%
Applied Social Sciences	9.2%	13.3%
Engineering	10.9%	11.2%
Linguistics, literature and arts	5.4%	6.8%
Multidisciplinary	6.0%	7.8%
Total	100.0%	100.0%

Source: Ministry of Science, Technology and Innovation

The impressive developments in graduate education and academic research, however, should be seen in light of the fact that they have occurred mostly within academic institutions. Brazil's science and technology field has been largely disconnected from the country's broader social and economic institutions, with weak ties to the productive sector. Thus, most people with doctoral degrees work either in universities (66 per cent) or in public administration (18 per cent), and only 1.6 per cent in industrial or agricultural activities (Galvão, Viotti, & Baessa, 2008 table 5) The small number of patents produced in Brazil also provides evidence of this deficient scenario (Pedrosa & Queiroz, 2013).

Public appreciation of science and technology

Brazil does not have a culture that is resistant or opposed to science. Technological gadgets and services are widely used, and access to computers and the Internet is growing rapidly. Public opinion surveys, as well as questionnaires administered to students in different contexts, show that the general population believes in the benefits brought about by science and technology (S&T). At the same time, however, people neither really understand nor participate in the scientific underpinnings of developments in S&T, and are therefore not concerned about their potentially harmful effects.

Access to technological devices and communications in Brazil occurred simultaneously with the country's rapid transition from a mostly rural to a predominantly urban society. Today, about 85 per cent of the population lives in urban areas, compared with just 50 per cent in the 1950s. Rural settlers were and still are among the poorest in the country, and for many of them, migration to the urban cities meant better access to jobs and services, even if conditions were far from ideal. At the same time, agricultural productivity increased with the growth of large-scale, mechanized agriculture. Up until the year 2000, less than 40 per cent of households had telephones and less than 10 per cent had computers, in part because of the public monopoly on telecommunications. With privatization and the development of new communication technologies, access to cell phones became universal (Figure 1), and today, about 50 per cent of households have access to computers and the Internet. In the 1980s, hyperinflation forced the banks to adopt

sophisticated technologies to keep bank accounts adjusted for daily currency devaluation, whereas most banking transactions are now done through the Internet and automated tellers. Since 2000, voting has been done electronically, and most of the government's tax procedures, including the collection of individual income-tax returns, are also done online.

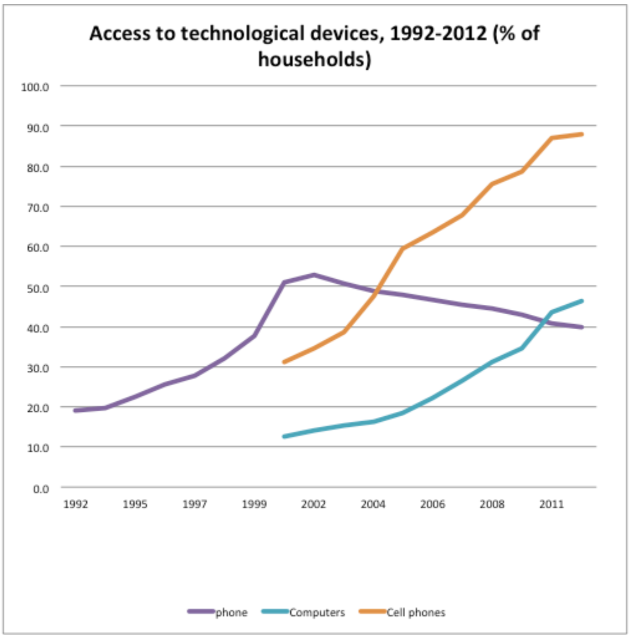

Figure 1 Source: Data from the Pesquisa Nacional de Amostra por Domicílios (PNAD), Brazilian Instiute for Geography and Statistics (IBGE).

In 2010, the Brazilian Ministry of Technology conducted a survey on the population's perceptions towards S&T that revealed an interesting paradox (Ministério da Ciência e Tecnologia, 2010): most respondents were unaware of any scientific research institution in the country and could not even name a single Brazilian scientist, but, at the same time, 25 per cent of respondents said they were well informed about S&T issues, compared with 11 per cent for Europe as a whole in similar surveys (figure 2).

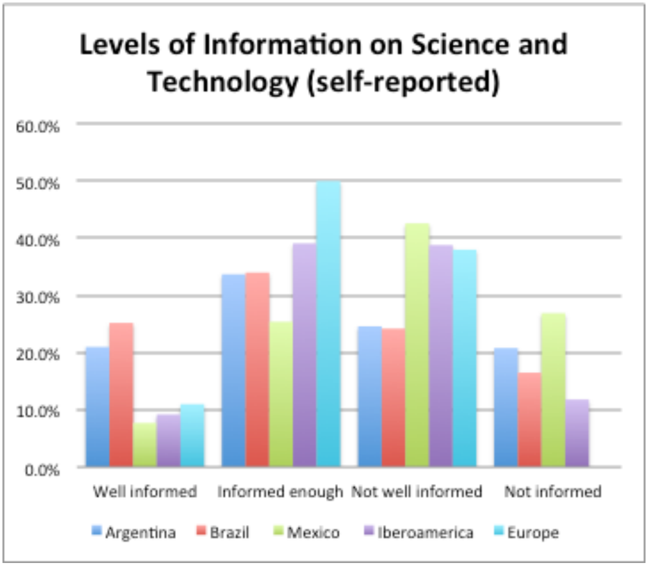

Figure 2. Adapted from (Polino, 2012 p. 83)

The survey showed that Brazilians are particularly interested in scientific issues related to the fields of environment, health and medicine and religion, and believe that they are mostly beneficial; the most important benefits are perceived to be in healthcare and better living conditions. When asked for their sources of information on S&T, TV is mentioned as the most frequent source, followed by reading newspapers and talking frequently with friends about S&T issues. The most credible sources of information are medical doctors, journalists and religious priests, and the least credible are politicians. Scientists are mentioned as credible sources by just 5 per cent of respondents.

The reference to religious priests made by some respondents can be linked to the current state of religiosity that prevails in Brazilian society. Brazil is the largest Catholic country in the world, but African religions and practices have also survived from former slaves, and, in the last decades, different branches of evangelical religions have grown very rapidly among the urban poor (barely any other religious traces from the original native population have survived). Although most Roman Catholics are not active churchgoers, the religiosity practiced by Evangelists, African cults and Spiritists share a common deep belief in revelation, magic and the presence of the dead among the living, a world of mysteries that many would expect science to eventually confirm, rather than to demystify.

A similar appreciation for science appears in the Brazilian results of the Program for International Student Assessment (PISA) assessment carried out by the Organization of Economic Co-Operation and Development (OECD) in 2006 (OECD 2007 (OECD, 2007)). The respondents were 15-year-old students then at the same educational level in each country. The table below presents the main results of appreciation of science by students in a few selected countries. The survey shows that the students most optimistic about the social benefits of science were those from Thailand, China, Tunisia, Brazil and Jordan, while those most pessimistic were from Northern Europe, including Germany and Denmark (table 3).

Table 3 - Percentage of students agreeing or strongly agreing with the following statements (selected countries):

	China (Taipei)	Brazil	OECD average	Germany	Denmark
Science is important for helping us to undestand the natural world	96	96	93	91	94
Advances in Science and Technology usually improve people's living conditions	98	94	92	89	91
Science is valuable to society	96	93	87	76	93
Advances inscience and technoogy usually help to improve the economy	94	77	80	73	73
Advances in science and technology usually bring social benefits	93	84	75	67	56

Source: OECD 2006 vol 1 p. 129

Science proficiency

In contrast to their high appreciation for science, Brazilian students actually had much less scientific knowledge than their counterparts in other countries. The graph below shows the distribution of scientific proficiency on a six-point scale developed by OECD, in which zero means below the minimum expected, while five means outstanding performance for the age level. In Brazil, 28 per cent of the 15-year-old students were below the minimum, and only 0.5 per cent were at the top, far worse than the OECD average, but also below Chile.

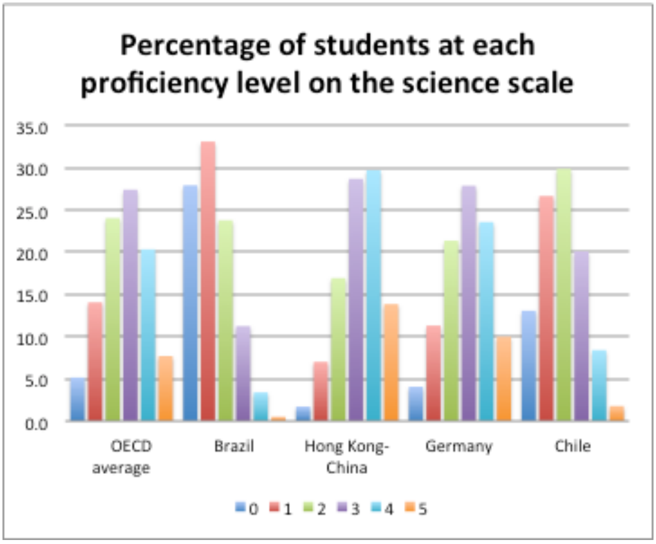

Figure 3. Source: OECD 2007

The low achievement in science by Brazilian students is consistent with their low achievements in the PISA assessments of language and mathematics and also with the National Assessment of Educational Achievement ('Prova Brasil') on language and mathematics carried out by the Brazilian Ministry of Education every two years. According to the Brazilian data, only 11 per cent of students at the end of secondary education and only 5.8 per cent of those in public schools achieve the minimum proficiency in mathematics expected for their level (Todos Pela Educação, 2012). This situation is made worse by the fact that at the age of 15, when all young people should be in their first year of secondary school, 47 per cent are still held in primary school, and 8 per cent have already left school. One year later, at age 16, retention in primary school is still at 27 per cent, and the percentage of dropouts rises to 14 per cent. Despite compulsory education, only 60 per cent of the Brazilian population ever finishes their secondary education.[2]

Historical roots – the King's plantation

The limitations of Brazilian education are rooted in the country's colonial past and the low priority given to education issues by Brazilian elites until only recently. Throughout its time of colonization by the Portuguese in 1500 to independence in

[2] Data from the Brazilian National Household Survey of 2011.

the early nineteenth century, Brazil was a source of wealth for the colonizers, based on forced labour used to extract gold and produce sugar and other agricultural products for the external market. Most of the native population was either decimated or expelled to remote areas, while the country became the world's main destination for African slaves. As opposed to the English in North America, the Portuguese seldom came to Brazil to settle with their families. The colonial administration was only concerned with the wealth it could extract from its colony—it was the King's plantation (Lang, 1979). As a result, no educational, scientific or cultural institutions were allowed to be established in the colony. Whatever education existed was provided by Catholic priests, with the Jesuits playing a special role in trying to convert the native population and organize them in agricultural settlements akin to what the Spanish did in their American colonies (Alden, 1992).

The European Renaissance, which gave rise to the development of modern science, never reached Portugal, and it remained untouched by Protestant reform and under the grips of Inquisition until the late eighteenth century. Then, under the leadership of Sebastião José de Carvalho e Melo, the Marquis of Pombal, Portugal made a concerted effort to modernize the country, modelling it on other European countries with respect to public management, economic efficiency, secularization and education (Maxwell, 1995). This late 'Portuguese enlightenment,' however, brought with it an increased concentration of power in the hands of the monarchy and did not include the creation of autonomous or semi-autonomous learned institutions—scientific societies, modern universities—or spaces for individual entrepreneurship associated with the development of modern capitalism elsewhere in Europe (Ben-David, 1965).

In 1808, the Portuguese Court moved to Brazil fleeing the Napoleonic Wars and established a few education and research institutions, which were retained and expanded following independence in 1822. These included, for example, a military and engineering school in Rio de Janeiro, a medical school in Bahia and a mineral collection in Rio de Janeiro, which later became a national museum. Throughout the nineteenth century, Brazil was an independent monarchy ruled by a branch of the Portuguese Royal Family, with an economy based on slave labour working on

the traditional sugar plantations and, later, in coffee production. Brazil's second emperor, Pedro II, who ruled from 1840 to 1889, was very interested in science and even became a member of the French Academy of (Schwarcz, 1998). During his tenure, a few new research institutions and institutions of education were established, many of them overseen by French leads, including an astronomic observatory and a mining school modelled on the French École de Mines (Carvalho, 1978). Nevertheless, little or nothing was done to build up a public education system, and most of the population—slaves and former slaves, children born from the miscegenation of Brazilian Indians, Portuguese immigrants and slaves—remained illiterate, living in the countryside or in the outskirts of the emerging urban centres along the coast.

Things began to change in 1850, however, when the British succeeded in putting an end to the slave trade and the slave-based economy started to collapse. Slavery was officially abolished, in 1888, and in 1889 a military coup turned Brazil into a republic. From the late nineteenth to the early twentieth centuries, Brazil became a significant destination for immigrants from Italy, Germany and other European countries, as well as from Japan, who came mostly as indentured labourers to work on the coffee plantations. The immigrants—about 4 million between 1884 and 1933—brought with them their cultural and religious institutions, including schools for the children. In the early twentieth century, the state of São Paulo, the hub of coffee production and the richest in the country, began creating public schools, as well as several professional and research institutions in engineering, medicine, agriculture and biology, some of them under the leadership of foreign immigrants. Tropical diseases plagued the country's main ports, and a tropical research institute was created in Rio de Janeiro in 1900 to deal with the problem, inspired by France's Pasteur Institute.

The 'Brazilian Enlightenment'

To some extent, the end of slavery and the monarchy can be viewed as the period of intellectual and cultural enlightenment in Brazil. The new generation of people educated in engineering and medicals schools, in Europe in some cases, searched for their place in society. They tended to stress the value and importance of

specialized knowledge as an alternative to the more established ways of thinking based on religious and legal traditions (Schwartzman, 1991a). Literature and knowledge of French positivism, as proposed by Auguste Comte, became mandatory for these new intellectuals. Positivist doctrine provided the engineers with the reassurance that they had the right and competence to rule society, which would be better and more civilized under their command. They campaigned against the monarchy in favour of universal education and better salaries for the working class; they opposed the church and all forms of corporatist organizations (universities, with their pretences of self-regulation, were perceived as one of them), and, above all, organized themselves in secret societies and conspired for power. They were so successful that their motto, 'Order and Progress,' is still enshrined in the Brazilian flag (Nachman, 1977). In order to modernize the country, they created a new planned city, Belo Horizonte, the forerunner of Brasilia, and led a sweeping urban reform of Rio de Janeiro, opening large avenues and destroying most of the old Portuguese-style city (Underwood, 1991).

The notion that society should be ruled by enlightened despots was pursued by the Getúlio Vargas authoritarian regime, which had been in power in Brazil from 1930 to 1965 (Dulles, 1967) and returned again in full force when the military regained power in 1964 and placed the country under the doctrine of national security. On the other side of the ideological divide were the Marxists, who also shared a fascination for rational planning, and important scientists educated in the 1930s and 1940s, inspired by the examples of Jean Frédéric Joliot-Curie in France and John D. Bernal in England, joined the Communist party.

Medical doctors too would not be left behind. They argued that Brazilian society should be cured of its ailments, which included not only the tropical diseases that plagued the population, but also 'racial degeneration' that many of them believed arose from racial miscegenation. At the turn of the century, Nina Rodrigues from the Bahia School of Medicine worked with biological theories that looked for links between physical traits and criminal behaviour. This research led directly to questions about the racial composition of the Brazilian population and the alleged problems people assumed to have derived from racial miscegenation. Character traits such as laziness, luxury or lack of discipline were no longer explained by old

environmental factors, but instead attributed to the new, biological and presumably more scientific theories. This diagnosis for the underpinnings of the Brazilians' troubles had to be followed by treatment and as such, eugenics became an important issue in Brazilian medical circles (Stepan, 1991). In 1929 the first Brazilian Congress of Eugenics was held in Rio de Janeiro with participants from several Latin American countries. It was followed by the establishment of a Brazilian Commission of Eugenics in 1931. Interventions were called for in many areas, from prenuptial examinations for the control of venereal diseases to the sterilization of alcoholics, syphilitics and those suffering from schizophrenia. Using the assumed superiority of the white race as their basis, some individuals within the field of eugenics worked on the expectation that there would be 'improvement' and 'correction' of the Brazilian population in the long term (Viana & Viana, 1982). Others, less 'optimistic,' called for strict limitations on racial intermarriage. After World War II, all these theories and proposals became, of course, unacceptable, but the issues of sanitation, preventive medicine and universal healthcare, supported since 1915 by the Rockefeller Foundation, have remained strong among significant sectors of the medical profession up until today (Cueto, 1994; Lima, 2007).

The enlightenment also reached the field of arts, literature and education. In 1922, a famous 'week of modern art' took place in São Paulo, bringing together painters inspired by the European avant-garde and authors writing literature and poetry in language free of the strict academicism that had dominated Brazilian literary circles until that point (Resende, 2000).

Public education also figured into the enlightenment agenda. In the 1920s, a series of national education conferences brought together intellectuals, religious leaders and businessmen to discuss the establishment of a public education system that could at long last raise the population out of illiteracy. In 1932, a 'Manifest of the Pioneers of the New School' was published, inspired by the ideas of John Dewey, proposing for the first time the creation of a national public education system. It would be a long time, however, before its actual implementation (Azevedo, 1932; Borges, 1994). In 1931, the national government established the Ministry of Education, Culture and Health and approved a bill that regulated the initiation of

the first universities. The new ministry's energy was invested, for the most part, into the establishment of a national university and the regulation of secondary education in all its details (Schwartzman, Bomeny, & Costa, 2000). Local governments were supposed to build up and improve primary education, but did little. By 1950, 50 per cent of the Brazilian population over 15 was still illiterate.

Although most of the Brazilian economy remained based on agricultural products and mining, starting in the 1930s, the national government and intellectuals became convinced that the country could only develop through industrialization and import substitution, to be fostered by public investments and central economic planning. This view gained new momentum in the 1950s under the influence of the economists of the United Nations Commission for Latin America (ECLAC) (Hirschman, 1968a, 1968b). It is remarkable that, in reading through the economics literature of this period, there is no mention of education-related issues, in spite of the growing importance of the international economics literature on human capital (Becker, 1964; Schultz, 1960).

The roots of contemporary science

The first Brazilian university, the University of São Paulo, was inaugurated in 1934. It brought together pre-existing professional schools in engineering, medicine and agriculture, among others, and imported a small group of researchers from Germany, France and Italy to staff its new 'Faculty of Philosophy, Sciences and Letters.' Within this faculty, several of the most significant research traditions in the country in physics, chemistry, biology, mathematics and the social sciences were inaugurated. Other research lineages developed from older institutions such as the Oswaldo Cruz Institute for Tropical Diseases in Rio de Janeiro, the Butantã Snake Venom and the Biological Research institutes in São Paulo (Schwartzman, 1991b). At each of these places, it was possible to identify a leader born or educated in Europe, and they all had to struggle to keep autonomous research alive in the face of limited resources, demands for short-term applied work and bureaucratic encroachment from government authorities and politicians.

It was not until 1949 that S&T gained the attention of the national government, through the creation of the National Council of Scientific Research and a National

Centre for Physics Research. The expectation was that Brazil could rapidly acquire nuclear capabilities for energy and national defence, a project that did not prosper due to both international constraints on the transfer of nuclear technologies and the lack of technical ability in the country (Adler, 1987). These aspirations subsequently lost relevance and visibility, but corresponding institutions continued to function with reduced budgets.

In 1964 a military coup ousted the Brazilian civilian government and many leading scientists who had been politically active, mostly from the left, demanding a stronger role for S&T in public policy, lost their jobs and were forced into exile. Then, gradually, several policies were implemented to improve the quality of the country's universities and to give more priority to scientific and technological research. In 1968, a new law was introduced that initiated the rearrangement of Brazil's public universities following the US model, with academic departments and graduate programmes, replacing the old 1931 university legislation. The Brazilian Corporation of Agricultural Research (EMBRAPA) was established in 1972 under the Ministry of Agriculture, and was instrumental in increasing the productivity of Brazil's crops. In 1973 the government enacted the first National Plan for Scientific and Technological Development, succeeded by a second plan in 1976.

Under the presidency of General Ernesto Geisel, Brazil undertook a very ambitious project for economic, technological and political self-reliance that was made possible through rapid economic growth in the 1970s, but would soon be thwarted by the changing international economic environment of the late 1970s and early 1980s. The project relied on the strengthening of public-owned companies in the fields of oil, energy, electricity and communications and on heavy investment in capital goods, infrastructure and also in the field of S&T (A. B. d. Castro & Souza, 1985). An incomplete list of initiatives from those years in science and technology includes (Schwartzman, 1994):

- The placement of S&T under the responsibility of the economic policy authorities, which allowed for a much higher influx of resources to S&T than ever before;
- The creation of a new federal agency for S&T under the Ministry of Planning, the Financing Agency for Studies and Projects (FINEP), which was unencumbered by

civil service routines and restrictions and responsible for the administration of several hundred million dollars a year for S&T support;

- The establishment of a few large-scale centres for R&D, such as the Coordination for Graduate Programs in Engineering of the Federal University in Rio de Janeiro (COPPE) and the University of Campinas. These centres were geared towards technological research and graduate education in engineering and sciences;
- The beginning of several programmes of military research, such as the space programme and the 'parallel' nuclear programme, as well as the establishment of a weapons industry;
- The agreement with Germany for cooperation in nuclear energy, which was meant to create an autonomous capability in the construction of nuclear reactors based on locally reprocessed fuel;
- The establishment of a policy of market protection for the computer industry, telecommunications and microelectronics, linked to an emerging national private sector.

In 1984, during a period of economic stagnation, rising inflation and disorganization of the public sector, the military returned power to the civilians. By then, however, the institutional framework created by the military government had already been installed or was on its way, including the creation of a ministry of science and technology by the new civilian government, heralded by most of the scientific community as fulfilling their dream of placing S&T at the core of Brazil's national public policy. The new S&T bureaucracy associated with the scientists and researchers working in different institutions and organized in scientific and professional associations became a significant interest group; but although powerful enough to assure the maintenance and gradual increase of public resources allocated to them, it was not strong enough to actually place science, technology and innovation at the core of the country's education and public policies.

Education, science, technology and innovation in contemporary Brazil

The civilian governments that succeeded the military regimes after 1985 did not question or attempt to change the broad framework for S&T established by the Geisel regime of the 1970s, despite recommendations by an advisory commission

that stressed the importance of adjusting the system to the more flexible and market-oriented features of more advanced economies (Schwartzman *et al*. 1995 (Schwartzman, 1995)). The university model defined by the 1968 legislation created a small number of expensive public institutions, not all of them of good quality, which were unable to absorb the growing demand for higher education. This situation opened up the space for private institutions, providing mostly cheap undergraduate degrees by way of evening courses.

Today, more than 70 per cent of the students in higher education are enrolled in private institutions, while graduate education and research is concentrated in a few public universities such as the state universities of São Paulo and Campinas and the Federal Universities of Rio de Janeiro, Minas Gerais, Rio Grande do Sul and Pernambuco. CAPES, an agency within the Ministry of Education, regulates the country's graduate programmes through peer review committees and provides fellowships to graduate students. Support for scientific research is provided mostly by the National Council for Scientific and Technological Research (CNPq) and state science-supporting agencies.

The higher education legislation required that university professors have doctoral degrees, which the country did not produce, and this led to a rapid expansion of graduate programmes, and also to some efforts to send students abroad for graduate education. To control the quality of graduate education and research, the Ministry of Education implemented a strict assessment system based on publication, graduate education statistics and peer review. This assessment has been used to close down graduate programmes that are considered unacceptable, leaving very few programmes ranked at the top level required to keep up with international standards. Most of the doctors who graduate from Brazilian universities end up working in universities or are already working there when they get their degrees. The assumption is that the presence of professors with doctoral degrees who do research enhances the quality of undergraduate and professional careers, but, since research is concentrated in a few public universities and hardly exists in private institutions, most students do not benefit from it (Schwartzman & Balbachevsky, 2014).

Brazil has some interesting examples of research institutions creating partnerships and doing work relevant for the economy and society (Schwartzman, 2008). The traditional Instituto Oswaldo Cruz in Rio de Janeiro, which is partnered with the Ministry of Health, produces vaccines used in public health programmes, and maintains several research programmes in the areas of pharmacology, tropical diseases and public health. Petrobrás, Brazil's national oil corporation, maintains large research programmes in partnership with universities, including the Faculty of Engineering of the University of Rio de Janeiro, for the development of deep-sea drilling technologies. The Catholic University in Rio de Janeiro also has a longstanding partnership with Petrobrás and other firms for the development of computer software and systems, and the Luiz de Queiróz School of Agriculture of the University of São Paulo works closely with EMBRAPA in agricultural research. The University of Campinas also has different research programmes associated with the private sector, and has generated a technological hub on its grounds; the Aeronautics Technological Institute (ITA), run by the Air Force, is at the heart of Embraer, a successful private producer of mid-range airplanes for the international market. However, most higher education institutions and research programmes tend to be isolated and inward looking, in part because they do not depend on external contracts to maintain themselves, but also because as part of the civil service, they have little flexibility to engage with external clients. In 2004 the Brazilian Congress approved an 'innovation law' to foster stronger links between universities and the productive sector (Matias-Pereira & Kruglianskas, 2005), but this legislation does not seem to have changed the picture very significantly.

Higher education as a whole has been expanding in recent years, but the number of people with higher education degrees is still only around 13 per cent of young adults between 25 and 35 years, and much less for the older generation. Figure 4 shows the distribution of the population with higher education by age group, which gives a perspective on evolution. Forty-five per cent get their degrees in the social sciences and social professions (particularly management and law) and 22 per cent in fields requiring scientific and technical competence, including the traditional professions of medicine and engineering. The third largest group is that of

schoolteachers. Until the 1990s, teacher education was done at normal schools and on secondary level, but in 1996, legislation was established that they should all get higher education degrees, in addition to their previous education, within the next 10 years, and that all new teachers should have a university degree. This target was not fully met, but led to the proliferation of evening and distance education courses in education and pedagogy that offered the teachers their required degrees (secondary school teachers need to have a higher education degree in their fields of specialization). The only sector that has been growing in relative size is that of healthcare services, with 7 per cent of the younger graduates.

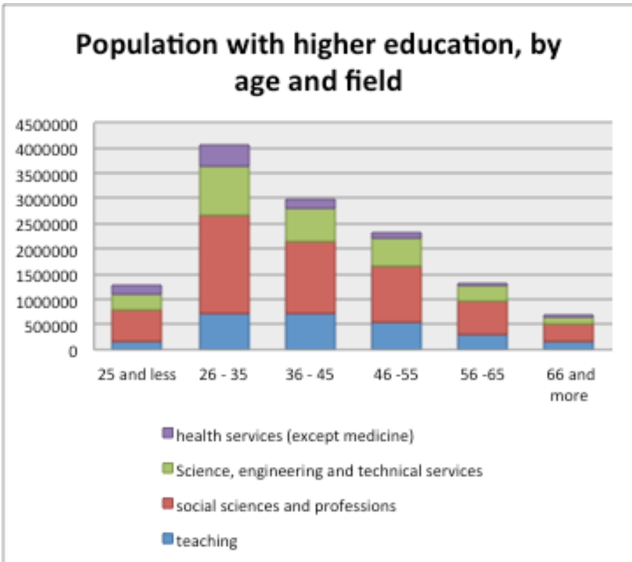

Figure 4. Source: Brazil, Demographic Census, 2010, microdata tabulated by the author

Brazil did not develop vocational education as an alternative to the conventional secondary school courses, and also lacks a significant sector of post secondary, short-term courses. Officially, all higher education graduates, irrespective of the institution where they studied, have a four-year degree ('bacharelado' or a teaching license), which takes longer for careers such as medicine and engineering. Revenues associated with university degrees vary hugely between different careers, with the highest incomes going to the traditional professions – medicine, engineering and law – and the lowest for administration, health services and teaching, which are the largest (Figure 5) (Instituto Brasileiro de Geografia e Estatística 2010). The reasons so many people go into these careers is that, because

of the inferior quality of their early education, they do not pass entrance examinations for the most prestigious fields and universities. Instead, they often need to work, can only study in the evening and cannot pay to attend the best private institutions.

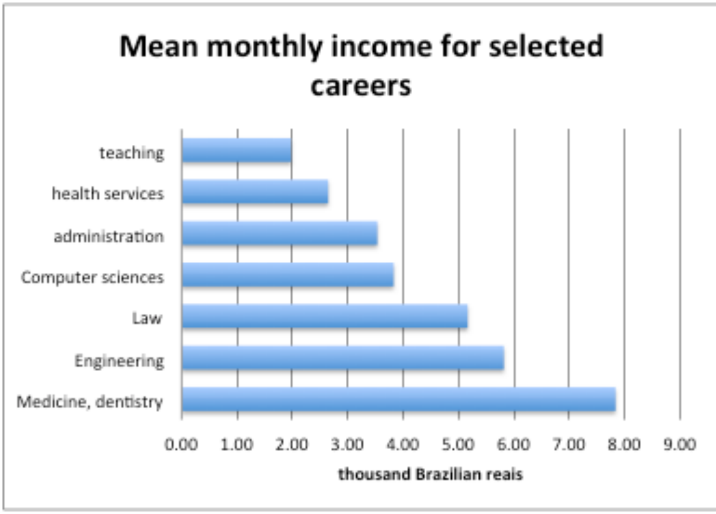

Figure 5. Source: Brazil's Demographic Census 2010, microdata tabulated by the author.

General education and STEM

The low status of the teaching profession is not the only reason students often do not excel, but it goes a long way towards explaining the low results obtained by Brazilian students in the national and international assessments mentioned earlier. In the past, primary school teachers were drawn from the middle classes, and studied in select public normal schools that may not have taught them much in terms of pedagogy and child development, but took care of their proficiency in language, mathematics and introductory sciences. Today, most teachers come from poor families and poor-quality public schools, and the components of teacher education emphasize broad sociological and teaching theory rather than the best teaching practices or the actual topics they are supposed to teach. Up to the fifth grade, there is one teacher per class, who is supposed to deliver all topics and classes to his or her students, including language, mathematics, science and the humanities. After the fifth grade, there is one teacher per subject based on the assumption that he or she is certified to teach their subject matter. In 2007 the Brazilian National Council of Education, a government body, estimated that the

country had a deficit of about 250,000 specialized teachers. The deficit was particularly acute in the STEM subjects.

Only in the 1990s did Brazil reach the point where most children are in school, but many drop out before completing mandatory education: currently, only 60 per cent of the population finishes secondary education. Finally, in more recent years, the problems of basic and secondary education has come up in the agenda of national and state governments, and there is a flurry of initiatives trying to deal with these, as well as debates about what should be done (Bruns, Evans, & Luque, 2011). Brazil spends about 6 per cent of its GDP on education, and there is the expectation that this will reach 10 per cent in the near future, creating the possibility of making the teaching profession more attractive. Different assessments show that there has been some improvement in the quality of education up to the fifth grade, but not for the higher grades.

Given the serious problems of functional illiteracy and innumeracy affecting so many students, it is understandable that science education has not been considered a priority. There is a general perception that the country is not educating enough middle-level technicians and engineers, but, at the same time, there are no signs of significant shortage of qualified manpower in the labour market (Schwartzman & Castro, 2013). One explanation for this apparent paradox is that businesses have adjusted to the manpower that exists in the country, making use of unqualified labour for construction and services, replacing qualified labour with technology and providing professional and vocational education through the national system of industrial apprenticeship (SENAI) and similar institutions managed directly by the business sector.

There have also been several initiatives to introduce inquiry-based education in the earliest school years, including a project run by the Brazilian Academy of Sciences to apply the methodologies used by the *main à pâte* science education programme in France (Charpak, Léna, & Quéré, 2005). A review carried out at the request of the Brazilian Academy of Sciences in 2009 found that, although many of these initiatives show promising results, they seldom go beyond the pilot stage, and are subject to vagaries associated with changes of education authorities and competing education programmes (Schwartzman & Christophe, 2009).

Another significant initiative is the National Scientific Olympic competitions in different areas including biology, computer science, physics or geography, done with the participation of scientific societies in each of the fields. Of these, the most consolidated is the National Olympics of Mathematics, which has also been the subject of assessments on its impact. In these competitions, the schools are encouraged to participate by registering their students, who go through a series of tests from local to national and international competitions. One function of these competitions is to find and encourage talents that can then be supported to continue their education at high levels of excellence. The other function is to get the schools active concerning the issues of science knowledge and competence, which could have a positive effect on students' performance as a whole.

In 2009, 43,864 public schools, with 19 million students (about 37 per cent of the student population), enrolled in the competition and 33,000 received prizes. An analysis of the impact of this participation in Brazil's national assessment of education showed it increased the students' performance by 1.9 points on the 500-point scale of the national assessment (Biondi, Vasconcellos, & Menezes-Filho, 2012). Another study showed that full participation led to an increase of 4.1 points on this scale (Soares & Candian, 2011). These effects, while statistically significant, are very modest, and do not change the broader picture of the low quality of Brazilian public education in general, and in mathematics and sciences in particular.

In 2011 the Brazilian government launched an ambitious programme called 'Sciences Without Borders,' to provide fellowships to 100,000 Brazilian students in four years to study abroad in STEM fields and to attract foreign researchers to come to Brazil. Most of the fellowships were for undergraduate students to go abroad for a year or so. This signified a radical departure from the established practice of Brazilian S&T agencies only providing support for graduate education in selected institutions abroad. Twenty-five thousand of these fellowships were provided by the private sector. From the beginning, the programme was recognized as an important effort to break the prevailing insularity of Brazilian S&T, but was received with scepticism because of the emphasis on undergraduate fellowships and the improvised way in which it was implemented, without the

participation of the country's education, scientific and technological institutions, and without a clear notion of what these students could accomplish during these brief spells abroad (C. D. M. Castro, Barros, Ito-Adler, & Schwartzman, 2012). In January 2014, the programme's website stated that 45,000 fellowships had been granted, 36,000 of those for undergraduate students, mostly to the US, UK and France (Portal Ciência Sem Fronteiras, 2014). For 2014, the estimated costs of the programme were about one billion Brazilian reais (US$ 400 million), and the Brazilian Association for the Advancement of Science (SBPC) expressed concern that this could lead to a reduction in the resources to support the National Research Council and regular scientific and technological research activities in Brazilian institutions (Escobar, 2013).

Conclusion

We can summarize this overview by saying that the Brazilian population, and the Brazilian culture, is neither opposed nor resistant to the advancements of S&T, but scientific and technological culture has remained restricted to a small segment of its population and has not really penetrated the education system, in spite of the growth in student enrolments and the existing requirements of scientific education in school programmes. The problem is not related specifically to STEM but to the quality of public education as a whole. The root of this situation is the history of slavery, which left the country with very high levels of social inequality, and a disregard for education that dates back to centuries of Portuguese colonization and extends to well into the twentieth century. The assessments of education quality, which started in the 1990s, showed some modest improvements in some states for fifth graders, but practically no improvement for ninth graders and students completing secondary education.

At the other extreme, there is a significant scientific and technological establishment, with many scientists getting involved in issues of general education; there is more data and research on education; public in education are increasing; and there is a growing national awareness that general education should improve. It certainly will, but it will take some time.

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